Rendezvous and Capture of a Martian Soil Sample in Orbit Around Mars, G. T. Chen, D. Liu, E. D. Skulsky[1], S. Weinstein, The authors are with the Jet Propulsion Laboratory, California Institute of Technology. [1]Correspondence should be sent to Eli David Skulsky, Jet Propulsion Laboratory, 4800 Oak Grove Drive, M/S 198-219, Pasadena CA, 91109, or by e-mail to Eli.D.Skulsky@jpl.nasa.gov.

Abstract: A proposed deep space semi-autonomous rendezvous approach will be presented as part of one strategy for returning a sample of Martian soil to Earth. This proposed approach involves placing a small canister containing a Martian soil sample in orbit around Mars. Subsequently, two types of sensors, a long range Radio Direction Finder (RDF) and a short range Laser Radar (LIDAR), on an orbiting spacecraft will be used to locate, rendezvous with, and capture the canister (known as the Orbiting Sample or OS). The Orbiter will then return the sample to Earth.

The proposed design would place the OS in a near-circular orbit around Mars using a small ascent vehicle. In addition to containing the Martian soil sample, the OS also includes components for its retrieval, including a solar-powered UHF radio beacon for receipt by the RDF and retro-reflectors for detection by the LIDAR. Once the OS is placed in orbit, a spacecraft (the "Orbiter") in a presumably different orbit will locate the OS, approach it, capture it, and return it to Earth. An RDF onboard the Orbiter will be used to measure the direction to the OS at ranges between 100 meters and 3000 km. A LIDAR also onboard the Orbiter provides the direction and range to the OS at shorter distances between 1 meter and 5 km. Finally, when the Orbiter is very near the OS, a capture mechanism working in conjunction with the LIDAR will secure the OS for return to Earth. After the capture is complete and prior to the Trans-Earth Injection maneuver, the rendezvous system, which consists of the RDF, LIDARs, capture mechanism, processors and associated electronics, can be jettisoned for mass reduction.

The rendezvous software will be flexible enough to accommodate various approach profiles; for background, previous analyses included a search phase, an intermediate phase, and a terminal phase. In the *search phase*, the RDF would acquire and track the OS. The RDF data would be transmitted to the ground in order to estimate the orbit of the OS and to design maneuvers which would align the orbit plane of the Orbiter to that of the OS. In the *intermediate phase*, the Orbiter would be placed into an OS approach orbit using ground-processed RDF data. Previous work focussed on the use of a double co-elliptic strategy (see fig. 1) used by Apollo. This strategy would allow ample ground-in-the-loop interaction prior to committing to an autonomous capture mode; future work would include looking at alternative approaches. When the Orbiter is within LIDAR range ($\leq$ 5 km), the rendezvous system would begin tracking the OS using the LIDAR, providing both direction and range to the OS. The double co-elliptic approach would allow time for the on-board software to verify the algorithm processing capabilities and compare the on-board results with solutions on the ground. At the appropriate time, the *terminal phase* would be initiated. This phase, which would include a completely autonomous final portion, would require a series of maneuvers which would place the Orbiter on the same orbital ellipse as the OS, but approximately 80 m in front of it. Following a "GO" from the ground, the rendezvous system would autonomously guide the Orbiter to the OS and capture it.

The proposed rendezvous algorithms are similar to and are based on those developed for Apollo and Shuttle; however, the rendezvous system will require significantly increased autonomy to accommodate a long round-trip light time.

This presentation will also include a phased develop-

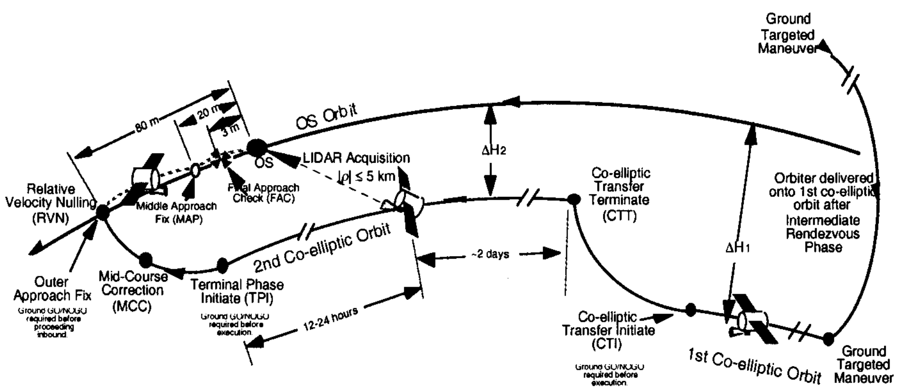

Figure 1 – Double Co-elliptic Strategy

ment plan for the proposed Rendezvous approach. The plan includes development of an end-to-end simulation and two options for flight demonstrations. One flight demonstration option is designed to validate rendezvous technology by using an RDF aboard the Mars '03 Orbiter to acquire and track UHF transmitters onboard Mars Global Surveyor and/or the Mars '01 Orbiter and possibly a test OS. The second flight demonstration option will validate a complete rendezvous and capture sequence of a test OS in Mars orbit using a CNES (French) orbiter carrying a NASA/ JPL rendezvous/capture payload.

Acknowledgment: The work to be described in this presentation was performed by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.